Army Research Laboratory

Curatorial Protocols for Capturing Single-Lap Joint Test Results Using the Materials Selection Analysis Tool Platform

by Wendy Kosik Chaney, Jonathan Kaufman, Daniel DeSchepper, and David Flanagan

ARL-RP-361 **March 2012**

A reprint from *Proceedings of the 35th Annual Meeting of the Adhesion Society*, New Orleans, LA, 26 February 2012.

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14. ABSTRACT

Candidate adhesives for Army applications can include nontraditional chemistries, which have largely unknown mechanical and durability properties as rigorously required for engineering design criteria. It is anticipated that a potential Army-motivated adhesive requirements standard would result in a candidate qualification pool of significantly greater numbers than well-established aviation counterparts. The Materials Selection and Analysis Tool (MSAT) database platform is currently being developed by the U.S. Army Research Laboratory (ARL) with guidance from NASA for capturing testing results. It is critical to document the adhesive response information without any prejudice, as models are currently not sufficiently well developed to describe the range of adhesive behaviors encountered for Army conditions. Therefore, our goal is to capture the entire experimental response curve, supportive pedigree information, and experimental descriptors, which will augment further data analysis. Increased research efficiency and improved data consistency are two significant drivers for automating mechanical testing/reporting protocols. The workflow scheme used here transfers and converts relevant load versus displacement raw data directly to MSAT as a verifiable digital asset. A separate analysis protocol is used to further reduce the data into defined and searchable metrics. Discovery protocols for culling the multifaceted data housed within MSAT to provide correlations between quasi-static adhesive performance and empirically observed response at high loading rates will eventually be developed.

15. SUBJECT TERMS

informatics, database, MSAT, single-lap-joint, adhesive

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Introduction

Adhesion is critical in armor applications. (1) The Army regularly needs to tailor multiple armor solutions to defeat rapidly emerging threats. (2) Therefore, there is a critical need to accelerate the development and/or selection of adhesive(s) for full spectrum protection. We are using materials informatics to efficiently capture, organize and explore adhesives structure-property-performance relationships for use in these armor solutions. The Materials Selection and Analysis Tool (MSAT) data management platform is currently being developed by ARL in collaboration with NASA for capturing adhesive testing results. MSAT's database infrastructure is a key component to the cyclic research methodology, illustrated in Figure 1, which allows for both the discovery of engineering solutions as well as directing fundamental science. ARL's critical role as data curator is to manage the data in such a way that ensures its viability to enhance fundamental understanding and facilitate rapid implementation to address newly emerging threats.

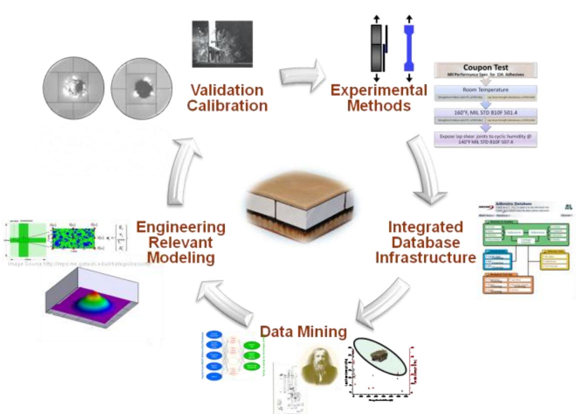

Figure 1: The cyclic materials informatics method.

The success of the cyclic materials informatics based method lies in providing a framework for a variety of subject matter experts to communicate and document their testing and research. An important objective for data curatorial protocols is ensuring the data, metadata and documentation to be trustworthy, valid, accurate and current. (3) In successful informatics cultures, this responsibility is shared across all interested parties; data creators, data curators, and data users.

Discussion

A significant challenge facing cyclic materials informatics is that several terms can have different meaning depending on the technical community. For example, the modeling and simulation community often describe data as experimental data, calculated data and metadata, where metadata refers to predicted data or latent data. However, in this paper we use the term metadata to refer to any data which increases confidence in a material's pedigree and the test specimen's provenance, to ensure data integrity. (4) In the case of the lap-shear testing, a partial list of metadata includes date of preparation, specimen lot identification (ID) information, basis testing standard, surface treatment, sample preparation procedure, calibration, operator, contact information of test lab, and perceived data of test engineer's observations.

Data integrity is best preserved using a work flow scheme which captures metadata and data at their source. (Figure2). Prior to testing, each lap-shear sample is given a MSAT generated unique specimen ID. The work flow scheme used here transfers and converts relevant load versus displacement raw data directly to MSAT as a verifiable digital asset. Adhesive materials ID, specimen and test metadata are captured in the test frame software prior to testing the lap shear sample. This metadata is exported directly as a text file, whose standardized format allows for automated upload into the adhesive database. Both the metadata file and the experimental test data file are tagged with the unique specimen ID to ensure proper data affiliation in the database.

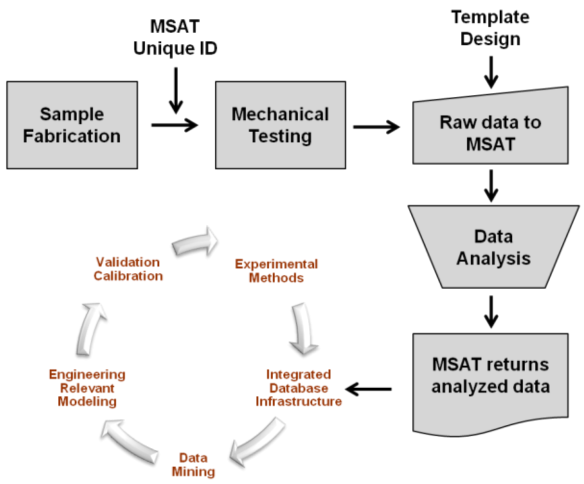

Figure 2: Lap-Shear workflow for preserving data integrity.

The mode of failure is a critical criterion that must be considered along with the strength in adhesive applications. Observing the failure surfaces provides insight into physical mechanism: adhesive, cohesive, or substrate failure. Image acquisition of the failure surfaces are accomplished via a digital scanner. High resolution scanners are widely available at a reasonable expense. Considerations into file type, resolution, depth of field, and labeling, although mundane in nature, are important to ensure the files are accessible and useful for future digital image processing. (5) Appropriate ARL "Branding", unique sample ID, and calibration scales were captured simultaneously to prevent unrecoverable accidental corruption or distortion of images.

This workflow protocol has results in enhanced testing methodologies and significantly reduced user-to-user variability through a change in our test engineer culture. Their hands on experience, observations, and concerns now have a way of being succinctly captured for rapid review by others as well as themselves. For example, while following the ASTM standards we initially encountered significant variance in bondline thickness using some paste adhesives, which resulted in visibly different load versus displacement curves. Scrutiny of the adhesive volumes, mixing and fillets allowed us to reduce the variance from 62% to 6% with shapes of the response curve becoming more uniform for the individual adhesives. Mitigating variance in lap shear sets has a profound effect on efficiency in data analysis. Initially, the protocol requirement to include "bad/failed" experimental data into the database was to prevent biased data sampling. It is now embraced as a critical step toward insight and improved quality control.

Because "failed" tests can often provide the most insight and development direction, the analysis protocol is kept separate from the data/metadata acquisition protocol in our workflow. The raw test data/metadata is reviewed and tagged as either 'valid' or 'not valid'. This valid dataset tag will allow the analyzed data to be used to further reduce the data into defined and searchable metrics. A tag of 'not valid' prevents the data from being used as part of a design allowable, but still keeps it available for study of why it 'failed'. Often the reported failure of an adhesive in the field lies not in the performance of the adhesive itself, but of the pre-treats, applications or other variable. This 'not valid' field allows for systematic study of such situations with mineable parameters. The ability to review the failure surfaces easily will provide insight into individual sample outlier response and possibly leverage commercial image analysis programs to quantify the mode-mixity of the failures.

Our ultimate intention is to advance adhesives through government, industry, and academia collaboration. (6) (7) We strive to present our data and analysis templates for export so they may be used with public domain, open architecture and/or standard file types. If a dataset is tagged as valid, an analysis algorithm is applied. Currently, the single-lap-joint results are quantified using a semi-automated spreadsheet analysis routine that calculates the apparent yield strength, maximum strength, area under the curve, and extension at failure. Including documents such as technical notes, experimental procedures, digital image/video, and analysis protocols strengthen the database's primary content. Cultural changes in data collection helps use the database at its full potential and future projects move faster. The ability to “dig down” through the database and successfully get complex data curves as well as their pedigree and test history provides significant advantage in addressing models and analysis.

Conclusion

The development of cyclic materials informatics will have a significant impact on the reliability of data generated in the laboratory, future adhesive development, and the rapid integration of solutions to emerging challenges. The generation of workflow protocols provides the ability to identify and eliminate sources of user-to-user variation. In addition, the identification of these variation sources during testing provides insight into potential issues that may arise during implementation. Through the generation and collection of adhesive data into a searchable database material trends that are not readily apparent can be realized providing direction for fundamental studies. In particular, important insight can be gained through “failed” tests that are often not reported due to unintentional bias. As a result, we feel that the development of a cyclic materials informatics will lead to enhanced development and understanding of adhesives resulting in dramatically improved development timescales and costs.

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